Homogeneity of Farm Labor: A Dual Approach

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Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting Corpus Christi, Texas, February 6-9, 2011

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Abstract

The assumption of homogeneity between family and hired farm labor is common in farm labor research. Controlling for region and farm size, this study employs a seemingly unrelated regression analysis to jointly estimate a translog cost function and factor cost shares to determine the elasticity of substitution between hired and family farm labor. The results show an evidence of heterogeneity of farm labor in both cash grain and hog farms in the U.S. There is further evidence that the elasticity of substitution is unitary and the cost minimizing ratio of hired and family labor is not independent of time. Regional factors were found to have little effect on the substitutability of farm labor, whereas farm size was found to have a significant influence on the relationship between hired and family labor.

Keywords: Farm labor, heterogeneity, homogeneity, cash grains, hogs, seemingly unrelated, substitution, hired labor, family, labor

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Introduction

A convenient assumption in the theoretical and empirical farm production literature, particularly in relation to the farm household model, is homogeneity of farm labor. In the foundational work on farm household models by Singh, Squire, and Strauss (1986), it is that stated that family and hired labor are assumed perfect substitutes and can be added directly. This implies that each additional unit of family and hired labor has an identical impact on production, costs, and profits. This assumption continues in more recent research (Blanc et al. 2008); however, family and hired labor may demonstrate differing impacts on the production processes of the farm (Deolalikar and Vijverberg 1982, 1978; Huffman 1976).

Consider a situation in which a farm operator's child is now of legal age to work full-time on the farm. This individual has been raised on the land, is familiar with the farming operations, and has likely established a relationship with their co-workers. Contrast this with a hired worker that does not have in–depth knowledge of the particular farmland and knows neither their co-workers nor the daily workings of the farming operation. A steeper learning curve can be expected for the hired worker relative to family labor, *ceteris paribus*.

Conversely, family labor might shirk because of greater job security and less motivation to work at the highest output levels. It can be argued that hired labor would then have a higher contribution to the production than family laborers. Again, farm labor would not be homogeneous. The direct implication of heterogeneous farm labor is that the notion of a single demand curve for farm labor should be abandoned—demand for family and hired labor should be considered separately.

Aside from the theoretical consequences, the merits of assuming homogeneity of farm labor—between family and hired labor—are also of interest from an empirical perspective. If farm labor is heterogeneous then the researcher must consider the tradeoffs of introducing an additional explanatory variable in the farm production model. For flexible functional forms, an additional explanatory variable may result in increased statistical issues like multicollinearity. Conversely, omission of either family labor, hired labor, or other factors of production may result in misspecification of the model and decreased technical efficiency. If the decision is still to assume homogeneity of farm labor, then the researcher should be aware of the implications.

The objective of this paper is to test the concept of homogeneity in farm labor while making no *a priori* assumptions as to the substitution relationship of farm labor. A flexible cost function approach is used, thereby allowing the data to reveal the relationship between hired and family labor. In this study we consider farms specializing in cash grain crops and hog production are analyzed separately. Hog farms are vertically integrated and generally more labor intensive than other farm types (Key and McBride 2007). Cash grain farms are relatively less reliant on labor—due to the increasing use of specialized machinery—and receive substantial farm program payments (USDA 2010) Additionally, the literature has shown that operators and spouses of cash grain farms have a higher likelihood of participating in work off–farm work (Ahearn et al 2006).

Using farm-level data, seemingly unrelated regression (SUR) method, and controlling for both farm size and ERS resource regions the results reject the null hypothesis of homogeneity across regions. The results also show heterogeneity in farm labor for both cash grain and hog farms. There is further evidence that the elasticity of substation is unitary. Hicks-neutral technical change was also rejected for the trials involving regional controls, meaning the cost minimizing ratio of hired and family labor is not independent of time. Controlling for farm size, homogeneity of farm labor can be rejected across all farm sizes for cash grain farms, both including and excluding corn. Both small and large hog farms exhibited a unitary elasticity of substitution, but the largest hog farms exhibited far greater substitutability than any other group ($\sigma_{ij} = 120.95$). Finally, the study, after controlling for farm size, failed to reject Hicks-neutrality for all trials.

<u>Theoretical Considerations and Literature Review</u>

Consider a version of the farm household model as proposed by Blanc et al. (2008) and derived from Dawson (1984) where the decision to allocate labor to off-farm work and hire farm labor is separated into four regimes—assuming hired and family labor are perfectly substitutable. The farm household is expected to follow a utility maximization framework:

$$Max\ U = U(L_{ei}(L_F, L_O), I(L_F, L_O)) \tag{1}$$

where U denotes utility as a function of leisure (L_{ei}) and income (I). Both farm household income and the time devoted to leisure are a function of the time devoted to farm labor (L_F) and time devoted to off-farm labor (L_O). Utility maximization in equation 1 is subject to the available hours allocable (T) to leisure, farm labor, and off-farm labor (equation 2) and full income constraint (equation 3). The full income constraint is defined as the sum of income from off-farm labor (wL_O), farm profits (π_F), and other household, non-labor income (V) minus the total expenditure on consumption goods (P_yY). Specifically,

$$L_{ei} + L_F + L_O - T = 0 \tag{2}$$

$$wL_O + \pi_F + V - P_yY = 0 \tag{3}$$

$$L_{ei}, L_F, L_O \geq 0 \tag{4}$$

Non-negativity constraints (equation 4) for time devoted to leisure, farm labor, and off–farm labor are also included.

Farm profits are further defined as the value of farm production minus the cost of inputs to production. Specifically,

$$\pi_F = P_f f\left(L, X_f\right) - w_f X_f \tag{5}$$

Now, let $f\left(L(L_F, L_H), X_f\right)$ be a Cobb-Douglas production function of the following form:

$$f\left(L(L_F, L_H), X_f\right) = AL^{\beta_1} \prod_{i=1}^{n} x_i^{\beta_i} \tag{6}$$

where X_f is a vector of farm inputs and $L(L_F, L_H)$ describes the farm labor input as a function of hired and family labor.

Let us now consider two alternative definitions of the labor input variable in the farm production function. The common approach to the farm household model, which assumes perfect substitution between labor inputs, is represented by L^O:

$$L^O = \alpha_1 L_F + (1 - \alpha_1) L_H \tag{7}$$

Alternatively, the relationship can be characterized by a quadratic function where the elasticity of substitution between hired and family labor is non-constant.

$$L' = \alpha_0 + \alpha_1 L_F + \alpha_2 L_H + b_1 L_F^2 + b_2 L_H^2 + b_3 L_F L_H \tag{8}$$

The Lagrangian ($\mathcal{L}$) can be onstructed for the outlined maximization problem with the following first order conditions:

$$U(L_{ei}(L_F, L_O), I(L_F, L_O)) + \lambda(L_{ei} + L_F + L_O - T) \tag{9}$$

$$+\delta(wL_O + \pi_F + V - P_y Y)$$

$$\frac{\partial \mathcal{L}}{\partial L_O} = -\frac{\partial U}{\partial L_{ei}} + w\frac{\partial U}{\partial I} = 0 \longrightarrow w = MRS_{L_{ei},I} \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial L_F} = -\frac{\partial U}{\partial L_{ei}} + \left(\frac{\partial \pi_F}{\partial L_F}\right)\left(\frac{\partial I}{\partial \pi_F}\right)\frac{\partial U}{\partial I} = 0 \longrightarrow \alpha_1 w_f + \phi = MRS_{L_{ei},I} \tag{11}$$

Generalizing from Blanc et al. (2008), four farm labor regimes can be obtained from the household utility maximization framework. Specifically,

$$w < MRS_{L_{ei},I} < \alpha_1 w_f + \phi \longrightarrow L_O = 0 \; and \; L_H = 0 \tag{12}$$

$$w = MRS_{L_{ei},I} < \alpha_1 w_f + \phi \longrightarrow L_O > 0 \; and \; L_H = 0 \tag{13}$$

$$w < MRS_{L_{ei},I} = \alpha_1 w_f + \phi \longrightarrow L_O = 0 \; and \; L_H > 0 \tag{14}$$

$$w = MRS_{L_{ei},I} = \alpha_1 w_f + \phi \longrightarrow L_O > 0 \; and \; L_H > 0 \tag{15}$$

Assuming the relationship between hired and family farm labor is described by L^O, then $\phi = 0$ and the resulting regime structure is that described by Blanc et al. (2008).

Alternatively, if farm labor is represented by L' then $\phi = (2b_1 L_F + b_3 L_H)$. This implies that if perfect substitutability between farm labor inputs is incorrectly assumed and $\phi > 0$, then the results of the farm household model are biased towards labor regimes where hired labor is expected to be positive (equations 14 and 15). Conversely, if perfect substitutability between farm labor inputs (between hired and family labor) is incorrectly assumed and $\phi < 0$, then the results of the farm household model is biased towards labor regimes where hired labor is expected to be zero (equations 12 and 13).

In addition to L^O and L', farm labor inputs can also be modeled using a Cobb-Douglas production function.

$$L'' = L_F^{\alpha_1} \mathrm{L}_{\mathrm{H}}^{(1-\alpha_1)} \tag{16}$$

The assumption of strict essentiality imposed by equation (16) has significant consequences which renders equation (11) and the related regime structure (equations 12-15) inapplicable. Rather than ϕ exhibiting an additive relationship, it will now be multiplicative (equation 17) and $\phi = \left(\frac{L_H}{L_F}\right)^{1-\alpha_1}$.

$$\frac{\partial \mathcal{L}}{\partial L_F} = -\frac{\partial U}{\partial L_{ei}} + \left(\frac{\partial \pi_F}{\partial L_F}\right)\left(\frac{\partial I}{\partial \pi_F}\right)\frac{\partial U}{\partial I} = 0 \longrightarrow \alpha_1 w_f \phi = MRS_{L_{ei},I} \tag{17}$$

The labor function L'' does not allow corner solutions for family or hired farm labor; therefore, family and farm labor must be strictly greater than zero. The resulting labor regimes are now,

$$w < MRS_{L_{ei},I} = \alpha_1 w_f \phi \longrightarrow L_O = 0 \; and \; L_H > 0 \tag{18}$$

$$w = MRS_{L_{ei},I} = \alpha_1 w_f \phi \longrightarrow L_O > 0 \; and \; L_H > 0 \tag{19}$$

The farm household only faces the decision of whether to allocate labor to off-farm work.

Prior research in this area has been limited to estimation of production functions for farm output, generally of Cobb-Douglas form (Deolalikar and Vijverberg 1982; 1978). Nested in these models are production functions for farm labor. In some models *a priori* relationships regarding the substitution relationship have been imposed, while others have utilized flexible functional forms such as the quadratic production function to represent farm labor.

Additionally, prior research has focused on testing the homogeneity of farm labor through the direct estimation of primal functions rather than a dual approach. Deolalikar and Vijverberg (1982 and 1987) are two studies analyzing the homogeneity in farm labor in India and Asia, respectively. Deolalikar and Vijverberg (1982) estimated a Cobb-Douglas production function for farm outputs as a function of farm labor and other farm inputs. The farm labor input is represented by a second production function nested with farm production function. Using data from 268 districts in India (1970-1971) the authors estimated aggregate output of 22 major crops. The farm production function in which the nested CES production for farm labor was reduced to a Cobb-Douglas specification was found to demonstrate the best fit by a standard F-test.

In another study, Deolalikar and Vijverberg (1987) extended their prior research to include farms in India and Malaysia. A Cobb-Douglas production function was once again used for farm outputs, but a generalized quadratic production function (equation 8) was used to represent hired and family labor. A sample of 476 Indian and 100 Malaysian farm households, for 1974-1975 and 1976-1977, respectively, were used in the estimation of aggregate output. The hypothesis of perfect substitutability for hired and family labor was once again rejected.

Huffman (1976) demonstrated a similar result using a cross section of aggregate county data from the 1964 Census of Agriculture. Specifically, Huffman used data for 276 counties in Iowa, North Carolina, and Oklahoma. Huffman estimated the ratio of hired labor (L_H) and farm husband or wife (L_{Op}). The elasticity of substitution, σ_{ij}, between hired labor and farm wives was 1.152 and 0.682 between hired labor and farm husbands; therefore, the rate at which farm husbands can be replaced by hired labor is relatively lower than that of farm wives. In an absolute sense, both farm husbands and wives do not exhibit perfect substitutability with hired labor

Some potential weaknesses of the aforementioned studies are the rigidness of the production functions used and the assumed substitutability between hired and family labor. Another potential problem is simultaneity arising from estimating the primal function directly. This problem is addressed in the current research through the use of cost functions which utilizes input prices rather than quantities as dependent variables. The use of a flexible, translog cost function is also advantageous because it does not impose a prior relationship between hired and family labor.

Empirical Model

The flexible translog functional form is well established in the literature (Binswanger 1974; Berndt and Wood 1975; Diewert and Wales

1987; Bigsby 1994; Greene 2008). It allows for estimation with an unrestricted substitution relationship between factors of production.

$$ln(C_k) = a_0 + a_Y\, ln(Y_k) + \frac{1}{2} a_{YY} ln(Y_k)^2 + \sum_{i=1}^{5} \beta_i ln(P_i) + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \beta_{ij} ln(P_i)\ln(P_j) + \sum_{i=1}^{5} d_{iY} ln(P_i) ln(Y_k) + a_T T + \frac{1}{2} a_{TT} T^2 + \sum_{i=1}^{5} g_{iT} ln(P_i) T \quad (20)$$

The variable Y_k represents the respective quantities of hogs, all cash grains, and cash grains excluding corn outputs. The input prices for hired labor, family labor, capital, land, and fertilizer/chemical/pesticide expense (specific to cash grains) or feed expense (specific to hog production) are represented by the variables (P_i, P_j) in equation (20). Also included in the model are the constant (a_c) and time trend (*T*).

The parameters $a_0, a_Y, a_{YY}, a_T, a_{TT}, \beta_i, \beta_{ij,}\ g_{iT}$ and d_{iY} are estimated, with a particular attention given to the interaction term (β_{ij}) for hired labor and family labor. A homogeneity restriction (equation 21) is included to ensure a proportional increase in all factor costs results in a proportional increase in production. This assumption also maintains that a change in all factor prices will not change the relative quantities of each factor used (Bigsby 1994).

$$\sum_{m=1}^{3} a_m \,;\ m = constant, Y, YY \quad (21)$$

$$\sum_{i=1}^{5} \beta_{ij} = \sum_{i=1}^{5} g_{iT} = \sum_{i=1}^{5} d_{iY} = 0$$

Cost share equations are then estimated jointly with the translog cost function for *(n-1)* factors of production. By dropping one share equation, the system becomes non-singular and can be estimated by SUR (Greene 2008).

$$S_i = \frac{\partial \ln(\mathrm{C_k})}{\partial \ln(P_i)} = \frac{X_i P_i}{C_k} = \beta_i + \sum_{i=1}^{5} \beta_{ij} \ln(P_i) + d_{iY} \ln(\mathrm{Y_k}) + g_{iT}\mathrm{T} \qquad (22)$$

From the cost share equations (22) and the interaction effect (β_{ij}) from the estimated cost function, the Allen partial elasticity of substitution can be calculated using the following equation.

$$\sigma_{ij} = \frac{\beta_{ij}}{S_i S_j} + 1 \qquad (23)$$

In the end we need to determine the sign and magnitude of the elasticity of substitution between hired and family labor, σ_{L_H,L_F}. If β_{L_H,L_F} is positive and significant then as σ_{L_H,L_F} approaches infinity the assumption of perfect substitution between hired and family labor is increasingly justified. If β_{L_H,L_F} is equal to zero then $\sigma_{L_H,L_F} = 1$ and the substitution relationship between family labor and hired labor is consistent with a Cobb-Douglas technology, assuming Hicks-neutrality holds.

Data

The data used in this research is obtained from the 2006-2008 Agricultural Resource Management Survey (ARMS). ARMS is conducted annually by ERS and the National Agricultural Statistics Service (NASS). The survey collects data to measure the financial condition and operating characteristics of farm businesses, the cost of producing agricultural commodities, and the well-being of farm operator households.

The target population of the survey is operators associated with farm businesses representing agricultural production in the 48 contiguous states. A farm is defined as an establishment that sold or normally would have sold at least $1,000 of agricultural products during the year. Farms can be organized as proprietorships, partnerships, family corporations, nonfamily corporations, or cooperatives. Data is collected from a single, senior farm operator, who makes most of the day-to-day management decisions.

The survey design of ARMS allows each sampled farm to represent a number of farms that are similar, referred to as a survey expansion factor. The expansion factor, in turn, is defined as the inverse of the probability of the surveyed farm being selected. A weighted means (expanded via an expansion factor, which is the weight) procedure is used to extrapolate a representative sample to a population. This is based on the procedure that is specific to the ARMS (Dubman 2000).

Data on production cost, input prices, and output quantities were taken from ARMS for both hog producers and an aggregate of cash grain crops. The cash grains included in this study are corn, soybean, wheat, sorghum, and barley. To determine whether there is a structural difference between corn and the remaining cash grains, a system of equations is estimated both including and excluding corn. The substitutability of family and hired labor is also examined for hog producers. Multiple models are estimated for various combinations of crops, livestock, farm sizes, and regions; therefore, the number of observations will vary accordingly.

Both livestock and crop production are analyzed in this study to determine whether farm type has a significant effect on labor substitutability. Controls are included for ERS Resource Regions to determine whether labor is more substitutable regionally. This effect could be due to the heterogeneous product mix and/or labor market conditions in alternative regions. The sample data is also restricted to include only family farms and excludes any farm with zero values for the selected test variables. Additionally, controls for farm size are included in the model to determine whether labor is more/less substitutable on small or large farms. For brevity we only consider three farm sizes—namely small, large, and very large farms. Farms with sales less than $250,000 are considered small, those with sales between $250,000 and $499,999 are considered large, and farms with sales of $500,000 or more are considered very large.

For all trials, the sample is restricted to U.S. family farms, which comprises of approximately 98% of all U.S. farms (see Figure 1). The largest family farms and non-family farms employ most of hired farm workers. The share of work hours on large and very large family farms accounted for by hired labor amounts to 21.8% and 55.5%, respectively. A greater proportion of large and very family farms specialize in cash grains than any other agricultural commodity; additionally, 85% of total production and nearly 90% of all cash grain production can be attributed to family farms (Hoppe et al. 2007).

The largest share of large and very large family farms, as well as the majority of hired farm labor, comes from the Fruitful Rim region. This region comprises parts of Washington, Oregon, California, Idaho, Arizona, Texas, Florida, Georgia, and South Carolina (Figure 1). From the Current Population Survey and USDA (2010), half of all hired farm labor is located in the following five states: Washington, Oregon, California, Texas, and North Carolina. Figure 1 shows that four of the five states are located within the Fruitful Rim region. North Carolina, being the exception, is located outside the region but is a large producer of hogs as well as a highly labor intensive crop like tobacco.

ERS Resource Regions are used to determine financial, economic, and resource related issues affecting farmers and are characterized by similar farm attributes, commodities produced, physiographic, soil, and climate conditions (Isserman 2002). The West and Southwest regions employs approximately half of all hired farm labor. The Northeast is the most populated region in the U.S. yet employs the fewest number of hired farm laborers for crops or livestock. According to ERS (2000), the Fruitful Rim accounts for the largest share of large and very large family farms, while the Northern Great Plains has the largest of all U.S. farm operations.

The cost of hired labor (P_{L_H}) used in this study is defined as *WAGERATE* in the ARMS dataset. This is the National Agricultural Statistics Service (NASS) average wage rate for hired labor, including Social Security taxes for the year. The cost of family labor (P_{L_F}) is calculated as *(OPPD + SPPD)/ (OPHRS + SPHRS)*, where *OPPD* is the amount paid to the principal operator for farm work, *SPPD* is the amount paid to the spouse for farm work, *OPHRS* and *SPHRS* is the total annual hours worked on the farm by the operator and spouse, respectively. Other family members, such as children and siblings, devoting labor to the farm are omitted from the family farm wage calculation due to the lack of data.

The price of land (P_{Land}) is calculated as the value of land and buildings per acre. Cost of capital (P_K) is calculated as the ratio of total interest expense to total farm debt. These variables are included in both cost estimations for hogs and cash grain farms. A variable input that is specific to the output type is also included in for hogs and cash grains farms, respectively. Specifically, for hogs, the feed price per hog (P_{Feed}) and fertilizer, lime, and chemical expense per acre (P_{Chem}) for cash grains farms are included in the model. Total costs (C) are assumed to be variable; therefore, total cash operating expense is used as the dependent variable in the cost function. The cost function is estimated for three groups of farm products: hogs, all cash grains, and cash grains excluding corn. Quantities for product groups (Y_K) are included in the cost function for these respective groups.

Cost share equations are estimated for four of the five variable inputs—one share equation is dropped from the system to permit estimation. The cost share equation for land was omitted because this variable poses the greatest difficulty to accurately represent as a share of total cash operating expenses. Alternatively, the cost shares for capital, hired labor, family labor, fertilizer/chemical/pesticide expense, and feed expense were relative easy to calculate. The farm expenses related to interest payments, fertilizer/chemical/pesticides, and feed were reported directly by farmers in the ARMS survey. Therefore, the reported values were divided by total operating expenses to obtain cost shares.

The cost share for hired farm labor (S_{L_H}) was calculated as the sum of hired labor expense, contract labor expense, and labor fringe benefit expenses divided by total operating expenses. This definition fully accounts for the farm expenses attributable to hiring farm labor. Finally, the cost share of family labor (S_{L_F}) was calculated as the total amount paid to operators and spouses divided by the total operating costs. Since the data is pooled a time trend is also included in the model. A linear and squared term for time was included; as well as, an interaction term between time and each input price. This interaction effect will determine whether technical change occurred with regard to a specific input and whether Hicks-neutrality can be assumed. If the parameter for hired labor/time or family labor/time is significant, then the Cobb-Douglas production function, for example, is not appropriate for modeling the relationship between hired and family labor across multiple years. Hence a more general approach, like the translog or generalized quadratic production function, would be more suitable.

Results and Discussion

The null hypothesis of farm labor homogeneity rests primarily on the magnitude and significance of the interaction parameter (β_{L_H,L_F}). Hypothesis tests for significance were performed using both z tests and t tests because of the relatively small samples for some trials. There was no significant difference in results from the two tests in trials, but the likelihood of rejection, in smaller sample, is still theoretically higher for t test. Therefore, a more conservative hypothesis test is used in this situation and reported results are only given for the trials using the z test. Additionally, for all trials the error term for the cost and cost share equations were found to be highly significant (Breusch-Pagan test). Therefore, use of the SUR model provides increased efficiency in the estimation of the model.

For each output group, five trials were performed using various combinations of regional controls. For example, it may be expected that removal of the Fruitful Rim region and correspondingly the abundance of hired labor located in this region would alter the substitutive relationship of labor for cash grain farms. However, as seen in Table 2, such changes had no effect on the substitution relationship for cash grains, both including and excluding farms specializing in corn production. In fact, the only trial in which the results differed was the case of no regional controls for cash grains excluding corn. In which case, the elasticity of substitution for hired and family labor rose from 1 to 20.64. This rise, while significant, is still considerably lower than the value required for perfect substitution.

The trials including the Heartland, Northern Great Plains, Prairie Gateway, Fruitful Rim, and Basin and Range regions were found to have an elasticity of substitution equal to one. The entire east coast, namely the Northern Crescent region, is omitted from these trials. For the all regions trial, including corn, the addition of the Northern Crescent region and other East/Southeastern regions did not change the results. When the 203 corn farms in the Eastern region were removed from the sample, the results changed significantly for the all regions group. This provides evidence of a structural difference in labor heterogeneity between corn farms and the remaining cash grains for the Eastern U.S. In this sample, the degree of labor heterogeneity for the 203 corn farms in this region is sufficient to crowd out the labor substitution effects of 340 barley, wheat, sorghum, and soybean farms.

The results for hog farms (Table 3) were consistent with those for cash grain farms. Hired and family labor demonstrated significant heterogeneity and should not be assumed perfect substitutes. It should be noted that the trials for hog farms exhibited little variation in sample size and composition. The concentration of farms to a core regional set of the Heartland, Northern Great Plains, Northern Crescent, Prairie Gateway, and Eastern Uplands is not surprising considering the documented consolidation and concentration of the hog production industry (Key and McBride, 2007).[2]

Additionally, Hicks-neutrality could not be rejected for hog farms. The interaction effect between hired labor/time and family labor/time was found insignificant in all trials; therefore, the cost minimizing ratio of these inputs can be assumed constant over the period of study. This evidence, in conjunction with the revealed substitution relationship, leads to the conclusion that labor on hog farms is best represented using a Cobb-Douglas production function. However, the same result does not hold for the cash grain farms.

Table 4 shows the interaction effect between the farm labor inputs and time for each cash grain group. In both cash grain groups only the trials for the regional set for Prairie Gateway, Fruitful Rim, and Basin and Range did not reject Hicks-neutrality. The remaining trials demonstrated

[2] According to data from the USDA (2010), the top five hog producing states in 2007 (Iowa, North Carolina, Minnesota, Illinois, and Indiana) were responsible for 67% of all hogs produced domestically.

consistently that over time increases in the cost of hired labor are positively correlated with farm production costs. This can be explained by rising wages, therefore, imposing greater costs to hired farm labor. Family labor costs were found to have a negative relationship with farm production costs over time. This is consistent with the fact that most family labor receives net profits, at the end of the crop season, as payment for hours worked on the farm.

Specifically, the price of family labor was found by dividing the amount of net farm income paid to operators and their spouses by the number of hours worked on the farm by the operator and spouse. While this provides the effective wage rate earned by farm family, it is not received by the operator and spouse in set installments like hired laborers' pay checks. Farm operators and spouses most often are paid by withdrawing the farm profits in the form of an owner's draw. Therefore, their wage rate is determined by the overall profitability of the farm. Assuming farm revenue holds constant, as the cost of farm production falls farm profits will rise. This in turn will result in rising family labor wage rates.

Considering both the technical and substitution relationships of cash grain farm labor, the suggested functional form for representing farm labor would be a translog production function. For single year, cross-sectional data, this functional form can be reduced to the special case of Cobb-

Douglas technology. For time series, panel, or pooled cross-sectional data a time trend can be included to determine whether technological change is Hicks-neutral while still allowing the unitary substitution relationship between hired and family labor.

Testing for heterogeneity of farm labor across farm sizes resulted in three test groups for each output (Table 5). Labor on cash grains farms, including corn, exhibited a complimentary relationship for the smallest farms, but hired and family labor on large and very large farms was found to be substitutable at an approximately equal rate. Excluding corn from the cash grains resulted in a unitary elasticity of substitution across all farm sizes. The elasticity of substitution was also unitary for small and large hog farms, but very large farms increased substantially to 120.95 likely resulting from increased standardization of work and specialization.

These results support the expectations that the elasticity of substitution increases with farm size through the specialization of labor. Similarly, Blanc et al. (2008) found family farms in Europe were increasingly likely to use permanent hired labor as farm size increased. This allows family labor to specialize in managerial tasks while hired labor specializes in other non-managerial and operational labor.

Hicks-neutrality, with respect to family and hired labor, was not rejected for any of the output groups when controlling for farm size. For cash grains, both including and excluding corn, there was evidence of both constant and exponential technical change. Due to the variability in elasticity of substitution and differing degrees of technical change, a translog or quadratic functional form (equation 8), including both constant and squared time trends, may be the most appropriate representation of the relationship between hired and farm labor when controlling for farm size.

Conclusion

Most studies in time allocation research have often assumed homogeneity in hired and family farm labor. However, using farm-level data and a dual approach this research concludes that there is heterogeneity in hired and family farm labor for cash grain and hog farms in the U.S. Further, homogeneity of farm labor, between hired and family labor, is rejected across regions. There is further evidence that the elasticity of substitution is unitary. Hicks-neutral technical change was also rejected for the trials involving regional controls—cost minimizing ratio of hired and family labor is not independent of time.

Controlling for farm size, homogeneity of farm labor (between hired and family labor) was rejected across all farm sizes for cash grain farms. Both small and large hog farms exhibited a unitary elasticity of substitution, but the largest hog farms exhibited far greater substitutability than any other group. Finally, Hicks-neutrality was not rejected for any of the trials controlling for farm size.

This study compliments the previous literature first by supporting the results of the proposed models and secondly by addressing some of the weaknesses of previous studies. These weaknesses were data quality, estimation issues related to primal functions, and rigidity in the assumed functional forms. This research allowed the data to reveal the underlying nature of labor substitutability with minimal assumptions.

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Figure 1: ERS Resource Regions

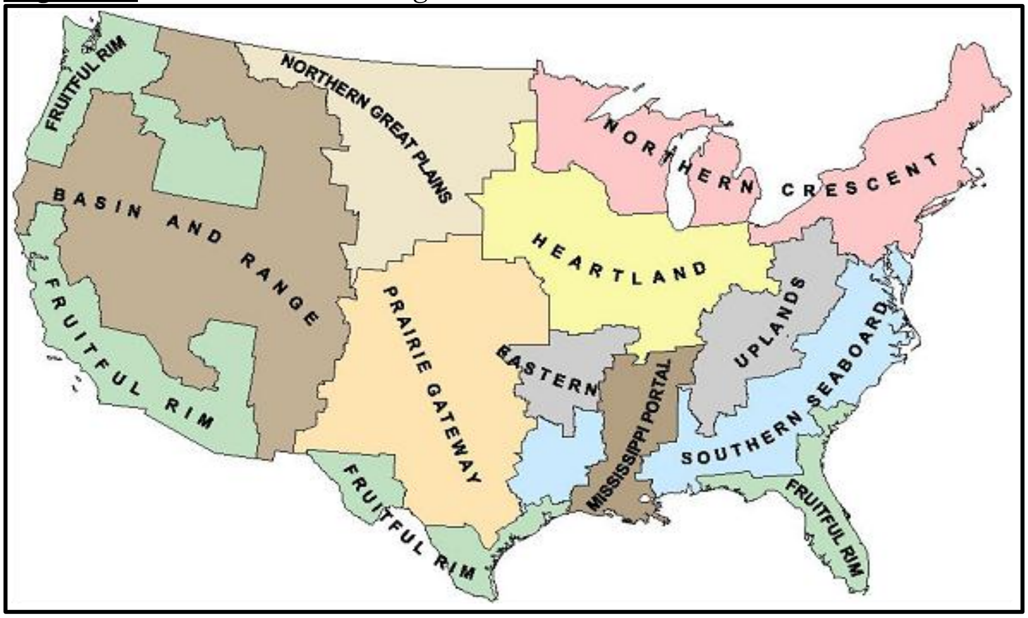

Table 1: Share of U.S. Farms Belonging to Each Organization Typology (Hoppe et al, 2007)

	Share
Small Family Farms	**90.28%**
Low Sales	18.78
Medium Sales	6.32
Residential/Lifestyle	39.73
Retirement	16.07
Limited Resource	9.38
Large Family Farms	**7.49%**
Large	4.08
Very Large	3.40
Non-Family Farms	**2.23%**

Table 2: Elasticity of Substitution, Cost Shares, and Estimated Interaction Effect for Hired and Family Farm Labor on Cash Grain Farms by Regions

	Including Corn					Excluding Corn				
ERS Resource Regions	**N**	β_{ij}	$\hat{S}_{HL}$	$\hat{S}_{FL}$	σ_{ij}	**N**	β_{ij}	$\hat{S}_{HL}$	$\hat{S}_{FL}$	σ_{ij}
Heartland, Northern Great Plains, Prairie Gateway, and Fruitful Rim	1081	0	11%	3%	1	983	0	11%	3%	1
Heartland, Northern Great Plains, Prairie Gateway, and Basin and Range	1049	0	10%	3%	1	958	0	10%	3%	1
Heartland, Northern Great Plains, Prairie Gateway, Fruitful Rim, and Basin and Range	1133	0	11%	3%	1	1034	0	11%	3%	1
Prairie Gateway, Fruitful Rim, and Basin and Range	355	0	12%	2%	1	329	0	12%	3%	1
All Regions	1577	0	12%	3%	1	1374	0.07	12%	3%	20.64

Table 3: Elasticity of Substitution, Cost Share, and Estimated Interaction Effect for Hired and Family Farm Labor on Hog Farms by Regions

ERS Resource Regions	**N**	β_{ij}	$\hat{S}_{HL}$	$\hat{S}_{FL}$	σ_{ij}
Heartland, Northern Great Plains, Northern Crescent, Prairie Gateway, Eastern Uplands, Southern Seaboard, and Mississippi Portal	185	0	10	2	1
Heartland, Northern Great Plains, Northern Crescent, Prairie Gateway, Eastern Uplands, and Southern Seaboard	185	0	10	2	1
Heartland, Northern Great Plains, Northern Crescent, Prairie Gateway, Eastern Uplands, and Mississippi Portal	181	0	10	2	1
Heartland, Northern Great Plains, Northern Crescent, Prairie Gateway, and Eastern Uplands	181	0	10	2	1
All Regions	190	0	10	2	1

Table 4: Interaction Effect of Hired and Family Labor Prices with Time for Cash Grain Farms

Cash Grains Including Corn	**Hired Labor**				**Family Labor**			
ERS Resource Regions	g_{iT}	**Std Error**	**Z**	**P>|z|**	g_{iT}	**Std Error**	**Z**	**P>|z|**
Heartland, Northern Great Plains, Prairie Gateway, and Fruitful Rim	0.102	0.039	2.64	0.008	-0.060	0.018	-3.36	0.001
Heartland, Northern Great Plains, Prairie Gateway, and Basin and Range	0.087	0.039	2.24	0.025	-0.051	0.018	-2.82	0.005
Heartland, Northern Great Plains, Prairie Gateway, Fruitful Rim, and Basin and Range	0.106	0.037	2.86	0.004	-0.053	0.017	-3.07	0.002
Prairie Gateway, Fruitful Rim, and Basin and Range	0.046	0.057	0.81	0.419	-0.037	0.031	-1.20	0.232
All Regions	0.083	0.03	2.73	0.006	-0.047	0.014	-3.26	0.001

Cash Grain Excluding Corn	**Hired Labor**				**Family Labor**			
ERS Resource Regions	g_{iT}	**Std Error**	**Z**	**P>|z|**	g_{iT}	**Std Error**	**Z**	**P>|z|**
Heartland, Northern Great Plains, Prairie Gateway, and Fruitful Rim	0.073	0.038	1.92	0.055	-0.065	0.018	-3.62	0.000
Heartland, Northern Great Plains, Prairie Gateway, and Basin and Range	0.068	0.039	1.76	0.079	-0.052	0.018	-2.88	0.004
Heartland, Northern Great Plains, Prairie Gateway, Fruitful Rim, and Basin and Range	0.084	0.036	2.35	0.019	-0.061	0.017	-3.54	0.000
Prairie Gateway, Fruitful Rim, and Basin and Range	0.035	0.057	0.62	0.537	-0.044	0.031	-1.39	0.166
All Regions	0.054	0.031	1.78	0.076	-0.043	0.015	-2.91	0.004

Table 5: Elasticity of Substitution for Hired and Family Farm Labor Controlling for Farm Size

Farm Size	**Cash Grains Including Corn**	**Cash Grains Excluding Corn**	**Hogs**
Small	-39.30	1	1
Large	36.58	1	1
Very Large	36.60	1	120.95